ANAMORPHIC CONVERTER

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an anamorphic converter suitable for a film camera, a television camera, a video camera or the like which is disposed on an image side of an imaging optical system in order to convert an aspect ratio to photograph an image having an aspect ratio different from that of an image pickup element, a lens device using the same, and an image pickup device such as a film camera, a television camera, or a video camera using the same.

Related Background Art

As a technique for converting an aspect ratio of an image to record and reproduce the resultant image, up to this time, various techniques have been proposed. In particular, for use in a motion picture, a system in which an image is optically compressed horizontally using an anamorphic lens to be photographed on a film, and during the reproduction, the image on the film is optically horizontally magnified to be projected using an anamorphic lens as well is generally used as a system for recording and reproducing an image in compliance with the CinemaScope form having an aspect ratio of 2.35 : 1. As an anamorphic converter, a large number of front

converters each mounted on a side of an object of an imaging optical system were proposed (refer to Japanese Patent Application Laid-Open Nos. 48-24048, 2-13916, 3-25407, 5-188271, 5-188272, 6-82691 and Japanese Patent No. 2,817,074 for example).

In addition, a rear converter mounted to an image side of an imaging optical system was proposed (refer to Japanese Patent No. 3,021,985 for example).

In recent years, promotion of high image quality of the video technique has progressed, and a digital cinema system for making a film of a scene with an HDTV (High Definition Television) system is in the progress of being popularized. In a digital cinema system, an image pickup element having an aspect ratio of 16 : 9 (1.78 : 1) is generally used. However, for the photographing complying with the CinemaScope form having the aspect ratio of 2.35 : 1, there has been demanded an anamorphic converter for effectively utilizing pixels on an image pickup element to enhance image quality.

It is required for an anamorphic converter for the cinema that the suitable aspect ratio conversion is made, no eclipse is generated, an effective image surface of an imaging optical system can be sufficiently utilized, reduction in a quantity of marginal ray is less, and high optical performance is provided throughout zooming and focusing.

As described in Japanese Patent Application Laid-Open Nos. 2-13916, 6-82691, and Japanese Patent No. 2,817,074, the front converter type has advantages that a structure is simple, and an effective diameter is ensured irrespective of a conversion ratio to avoid generation of the eclipse. On the other hand, there is encountered a problem that the size is large, and a change in astigmatism due to focusing occurs.

In addition, as a technique for correction of astigmatism due to focusing, there were proposed the techniques described in Japanese Patent Application Laid-Open Nos. 48-24048, 3-25407, 5-188271 and 5-188272. In these techniques, however, there is encountered a problem that correction means within a converter must be driven in conjunction with focusing in an imaging optical system, and hence a complicated mechanism is required.

The rear converter type has an advantage that there occurs no change in astigmatism due to focusing. However, a problem arises that when a conversion magnification on a vertical side and a conversion magnification are not suitably set, the eclipse is generated and a field angle of an imaging optical system is changed so that an effective image surface can not be sufficiently utilized.

As the rear converter type, there are a system

having no primary image formation as shown in FIG. 31, and a system having primary image formation as shown in FIG. 32.

In FIGS. 31 and 32, $\alpha 1$ is an emission inclination angle of axial marginal ray from an imaging optical system, and $\alpha 2$ and $\alpha 3$ are emission inclination angles of axial marginal ray from an anamorphic converter AC.

In case of the rear converter type having no primary image formation, as shown in FIG. 31, an axial marginal ray from the imaging optical system needs to be made nearly afocal with a negative lens. At the same time, since an off-axial chief ray is leapt up, an off-axial chief ray emission height hb2 from a converter final surface becomes large. Hence, a problem occurs that vignetting is increased to reduce a quantity of axial marginal ray, and an off-axial chief ray emission inclination angle $\alpha b2$ is increased to shorten an exit pupil, and thus an influence of the color shading by a color separation optical system becomes easy to be generated.

The system having no primary image formation, i.e., the rear converter in which both focal length conversion magnifications βx and βy are positive values is proposed in JP 3,021,985 B. In this case, however, since the rear converter is prescribed so that a positive refracting power is obtained in a

horizontal direction, and a negative refracting power is obtained in a vertical direction, the rear converter has an effect of lengthening a focal length in addition to an effect of converting an aspect ratio. As a result, there is a problem that a field angle becomes narrow, and if the field angle is tried to be ensured, then an image pickup means having a larger image size is required, and if the image pickup means having the larger image size is used, then an exit pupil position becomes relatively short so that an exit angle of an off-axial chief ray of a peripheral portion of a screen becomes large, and hence the shading or the like is generated.

SUMMARY OF THE INVENTION

In the light of the foregoing, it is an object of the present invention to provide an anamorphic converter of a rear converter system which is especially most suitable for a converter for the cinema, and which is miniature and excellent in optical performance.

According to a first aspect of the present invention, there is provided an anamorphic converter including at least an anamorphic lens disposed on an image side of an imaging optical system,

in which when a focal length conversion magnification in an arbitrary cross section X

containing an optical axis of the anamorphic converter is assigned βx, a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, an aspect ratio of an image pickup range in an image surface of the imaging optical system is assigned AR1, and an aspect ratio of an effective area of image pickup means is assigned AR2, the following relationship is established:

$$0.9 < (AR1 \times \beta x)/(AR2 \times \beta y) < 1.1$$

According to a second aspect of the present invention, in the anamorphic converter according to the first aspect of the invention, the anamorphic lens is provided within an afocal group.

According to a third aspect of the present invention, in the anamorphic converter according to the first aspect of the invention, both βx and βy are positive values, and the anamorphic converter has positive refracting powers in the cross section X and in the cross section Y.

According to a fourth aspect of the present invention, the anamorphic converter according to the third aspect of the invention further includes, from the imaging optical system side in a stated order, a first group of lenses having a negative refracting power, a second group of lenses including at least

two or more anamorphic lenses, and a third group of lenses having a positive refracting power.

According to a fifth aspect of the present invention, in the anamorphic converter according to the third aspect of the invention, the following relationship is established:

$$1 \leq (AR2^2 + 1) \times \beta y/(AR1^2 + 1) < 2.6$$

According to a sixth aspect of the present invention, in the anamorphic converter according to the first aspect of the invention, both βx and βy are negative values, and the anamorphic converter further includes at least one negative lens and two or more anamorphic lenses.

According to a seventh aspect of the present invention, there is provided an anamorphic converter including at least an anamorphic lens disposed on an image side of an imaging optical system,

in which when a focal length conversion magnification in an arbitrary cross section X containing an optical axis of the anamorphic converter is assigned βx, and a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, both βx and βy are negative values.

According to an eighth aspect of the present invention, there is provided a lens device,

including:

the anamorphic converter according to any one of the first to seventh aspects of the invention; and

the imaging optical system disposed on an object side with respect to the anamorphic converter.

According to a ninth aspect of the present invention, there is provided an image pickup device, including:

the anamorphic converter according to any one of the first to seventh aspects of the invention;

an imaging optical system disposed on an object side with respect to the anamorphic converter; and

image pickup means disposed on the object side with respect to the anamorphic converter.

According to a tenth aspect of the present invention, there is provided an anamorphic converter including at least an anamorphic lens disposed on an image side of an imaging optical system,

in which when a focal length conversion magnification in an arbitrary cross section X containing an optical axis of the anamorphic converter is assigned βx, a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, an aspect ratio of an image pickup range in an image surface of the imaging optical system is assigned AR1, and an aspect ratio

of an effective area of image pickup means is assigned AR2, the following relationships are established:

$$0.9 < (AR1 \times \beta x)/(AR2 \times \beta y) < 1.1$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) < 1$$

According to an eleventh aspect of the present invention, in the anamorphic converter according to the tenth aspect of the invention, the anamorphic lens is provided within an afocal group.

According to a twelfth aspect of the present invention, in the anamorphic converter according to the tenth aspect of the invention, both βx and βy are positive values, and the anamorphic converter has positive refracting powers in the cross section X and in the cross section Y.

According to a thirteenth aspect of the present invention, the anamorphic converter according to the twelfth aspect of the invention further includes, from the imaging optical system side in a stated order, a first group of lenses having a negative refracting power, a second group of lenses including at least two or more anamorphic lenses, and a third group of lenses having a positive refracting power.

According to a fourteenth aspect of the present invention, in the anamorphic converter according to the tenth aspect of the invention, both βx and βy are negative values, and the anamorphic converter further

includes at least one negative lens and two or more anamorphic lenses.

According to a fifteenth aspect of the present invention, there is provided a lens device, including:

the anamorphic converter according to any one of the tenth to fourteenth aspects of the invention; and

the imaging optical system disposed on an object side with respect to the anamorphic converter.

According to a sixteenth aspect of the present invention, there is provided an image pickup device, including:

the anamorphic converter according to any one of the tenth to fourteenth aspects of the invention;

the imaging optical system disposed on an object side with respect to the anamorphic converter; and

image pickup means disposed on the object side with respect to the anamorphic converter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of a wide angle end of Numerical Example 1 in an X direction and in a Y direction;

FIG. 2 is a longitudinal aberration view of Numerical Example 1 in the X direction under a

condition in which fx is 9.7 mm, fy is 12.9 mm, and an object distance is 2.5 m;

FIG. 3 is a longitudinal aberration view of Numerical Example 1 in the Y direction under a condition in which fx is 9.7 mm, fy is 12.9 mm, and an object distance is 2.5 m;

FIG. 4 is a longitudinal aberration view of Numerical Example 1 in the X direction under a condition in which fx is 37.3 mm, fy is 49.3 mm and the object distance is 2.5 m;

FIG. 5 is a longitudinal aberration view of Numerical Example 1 in the Y direction under a condition in which fx is 37.3 mm, fy is 49.3 mm and the object distance is 2.5 m;

FIG. 6 is a longitudinal aberration view of Numerical Example 1 in the X direction under a condition in which fx is 142.9 mm, fy is 189.0 mm and the object distance is 2.5 m;

FIG. 7 is a longitudinal aberration view of Numerical Example 1 in the Y direction under a condition in which fx is 142.9 mm, fy is 189.0 mm and the object distance is 2.5 m;

FIG. 8 is a cross sectional view of a wide angle end of Numerical Example 2 in the X direction and in the Y direction;

FIG. 9 is a longitudinal aberration view of Numerical Example 2 in the X direction under a

condition in which fx is 9.7 mm, fy is 12.9 mm and the object distance is 2.5 m;

FIG. 10 is a longitudinal aberration view of Numerical Example 2 in the Y direction under a condition in which fx is 9.7 mm, fy is 12.9 mm and the object distance is 2.5 m;

FIG. 11 is a longitudinal aberration view of Numerical Example 2 in the X direction under a condition in which fx is 37.3 mm, fy is 49.3 mm and the object distance is 2.5 m;

FIG. 12 is a longitudinal aberration view of Numerical Example 2 in the Y direction under a condition in which fx is 37.3 mm, fy is 49.3 mm and the object distance is 2.5 m;

FIG. 13 is a longitudinal aberration view of Numerical Example 2 in the X direction under a condition in which fx is 142.9 mm, fy is 189.0 mm and the object distance is 2.5 m;

FIG. 14 is a longitudinal aberration view of Numerical Example 2 in the Y direction under a condition in which fx is 142.9 mm, fy is 189.0 mm and the object distance is 2.5 m;

FIG. 15 is a conceptual diagram of an aspect ratio;

FIG. 16 is a conceptual diagram of an image circle and an image pickup range in an image surface of an imaging optical system;

FIG. 17 is a conceptual diagram of an image circle and an image pickup range after conversion made by a converter of the present invention;

FIG. 18 is a conceptual diagram of an effective area of an image pickup means;

FIG. 19 is a conceptual diagram of a display area of an output image in projecting an image;

FIG. 20 is a cross sectional view in a wide angle end before insertion of an anamorphic converter of Numerical Examples 1, 2, and 3;

FIG. 21 is a longitudinal aberration view under a condition in which f is 10.3 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 1, 2, and 3;

FIG. 22 is a longitudinal aberration view under a condition in which f is 39.5 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 1, 2, and 3;

FIG. 23 is a longitudinal aberration view under a condition in which f is 151.1 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 1, 2, and 3;

FIG. 24 is a cross sectional view in a wide angle end of Numerical Example 3 in the X direction and in the Y direction;

FIG. 25 is a longitudinal aberration view of Numerical Example 3 in the X direction under a

condition in which fx is -9.7 mm, fy is -12.9 mm and the object distance is 2.5 m;

FIG. 26 is a longitudinal aberration view of Numerical Example 3 in the Y direction under a condition in which fx is -9.7 mm, fy is -12.9 mm and the object distance is 2.5 m;

FIG. 27 is a longitudinal aberration view of Numerical Example 3 in the X direction under a condition in which fx is -37.3 mm, fy is -49.3 mm and the object distance is 2.5 m;

FIG. 28 is a longitudinal aberration view of Numerical Example 3 in the Y direction under a condition in which fx is -37.3 mm, fy is -49.3 mm and the object distance is 2.5 m;

FIG. 29 is a longitudinal aberration view of Numerical Example 3 in the X direction under a condition in which fx is -142.9 mm, fy is -189.0 mm and the object distance is 2.5 m;

FIG. 30 is a longitudinal aberration view of Numerical Example 3 in the Y direction under a condition in which fx is -142.9 mm, fy is -189.0 mm and the object distance is 2.5 m;

FIG. 31 is a conceptual view of an anamorphic converter of a type having no primary image formation;

FIG. 32 is a conceptual view of an anamorphic converter of a type having primary image formation;

FIG. 33 is a cross sectional view in a wide angle end of Numerical Example 4 in the X direction and in the Y direction;

FIG. 34 is a longitudinal aberration view of Numerical Example 4 in the X direction under a condition in which fx is 7.90 mm, fy is 10.44 mm and the object distance is 2.5 m;

FIG. 35 is a longitudinal aberration view of Numerical Example 4 in the Y direction under a condition in which fx is 7.90 mm, fy is 10.44 mm and the object distance is 2.5 m;

FIG. 36 is a longitudinal aberration view of Numerical Example 4 in the X direction under a condition in which fx is 30.24 mm, fy is 39.98 mm and the object distance is 2.5 m;

FIG. 37 is a longitudinal aberration view of Numerical Example 4 in the Y direction under a condition in which fx is 30.24 mm, fy is 39.98 mm and the object distance is 2.5 m;

FIG. 38 is a longitudinal aberration view of Numerical Example 4 in the X direction under a condition in which fx is 115.83 mm, fy is 153.12 mm and the object distance is 2.5 m;

FIG. 39 is a longitudinal aberration view of Numerical Example 4 in the Y direction under a condition in which fx is 115.83 mm, fy is 153.12 mm and the object distance is 2.5 m;

FIG. 40 is a cross sectional view in a wide angle and of Numerical Example 5 in the X direction and in the Y direction;

FIG. 41 is a longitudinal aberration view of Numerical Example 5 in the X direction under a condition in which fx is 7.34 mm, fy is 9.71 mm and the object distance is 2.5 m;

FIG. 42 is a longitudinal aberration view of Numerical Example 5 in the Y direction under a condition in which fx is 7.34 mm, fy is 9.71 mm and the object distance is 2.5 m;

FIG. 43 is a longitudinal aberration view of Numerical Example 5 in the X direction under a condition in which fx is 28.12 mm, fy is 37.18 mm and the object distance is 2.5 m;

FIG. 44 is a longitudinal aberration view of Numerical Example 5 in the Y direction under a condition in which fx is 28.12 mm, fy is 37.18 mm and the object distance is 2.5 m;

FIG. 45 is a longitudinal aberration view of Numerical Example 5 in the X direction under a condition in which fx is 107.72 mm, fy is 142.41 mm and the object distance is 2.5 m;

FIG. 46 is a longitudinal aberration view of Numerical Example 5 in the Y direction under a condition in which fx is 107.72 mm, fy is 142.41 mm and the object distance is 2.5 m;

FIG. 47 is a conceptual diagram of an aspect ratio;

FIG. 48 is a conceptual diagram of an image circle and an image pickup range in an image surface of a main lens;

FIG. 49 is a conceptual diagram of an image circle and an image pickup range after conversion made by a converter of the present invention;

FIG. 50 is a conceptual diagram of an effective area of an image pickup means;

FIG. 51 is a conceptual diagram of a display area of an output image in projecting an image;

FIG. 52 is a cross sectional view in a wide angle end before insertion of an anamorphic converter of Numerical Examples 4, 5, and 6;

FIG. 53 is a longitudinal aberration view under a condition in which f is 10.3 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 4, 5, and 6;

FIG. 54 is a longitudinal aberration view under a condition in which f is 39.5 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 4, 5, and 6;

FIG. 55 is a longitudinal aberration view under a condition in which f is 151.1 mm and the object distance is 2.5 m before insertion of the anamorphic converter of Numerical Examples 4, 5, and 6;

FIG. 56 is a cross sectional view in a wide angle end of Numerical Example 6 in the X direction and in the Y direction;

FIG. 57 is a longitudinal aberration view of Numerical Example 6 in the X direction under a condition in which fx is -7.11 mm, fy is -9.40 mm and the object distance is 2.5 m;

FIG. 58 is a longitudinal aberration view of Numerical Example 6 in the Y direction under a condition in which fx is -7.11 mm, fy is -9.40 mm and the object distance is 2.5 m;

FIG. 59 is a longitudinal aberration view of Numerical Example 6 in the X direction under a condition in which fx is -27.25 mm, fy is -36.01 mm and the object distance is 2.5 m;

FIG. 60 is a longitudinal aberration view of Numerical Example 6 in the Y direction under a condition in which fx is -27.25 mm, fy is -36.01 mm and the object distance is 2.5 m;

FIG. 61 is a longitudinal aberration view of Numerical Example 6 in the X direction under a condition in which fx is -104.37 mm, fy is -137.96 mm and the object distance is 2.5 m;

FIG. 62 is a longitudinal aberration view of Numerical Example 6 in the Y direction under a condition in which fx is -104.37 mm, fy is -137.96 mm and the object distance is 2.5 m;

FIG. 63 is a conceptual view of an anamorphic converter of a type having no primary image formation; and

FIG. 64 is a conceptual view of an anamorphic converter of a type having primary image formation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

(Operation 1)

Aspect 1

An anamorphic converter according to the present invention includes at least an anamorphic lens disposed on an image side of an imaging optical system, and the anamorphic converter is characterized in that when a focal length conversion magnification in an arbitrary cross section X containing an optical axis of the anamorphic converter is assigned βx, a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, an aspect ratio of an image pickup range in an image surface of the imaging optical system is assigned AR1, and an aspect ratio of an effective area of image pickup means is assigned AR2, the following relationship is established:

$$0.9 < (AR1 \times \beta x)/(AR2 \times \beta y) < 1.1$$

Aspect 1 is concerned with a condition under which the conversion magnification of the anamorphic

converter is suitably prescribed to thereby carry out the suitable conversion of an aspect ratio without generation of an eclipse.

Equation 1 exhibits with a condition under which the suitable aspect ratio conversion is carried out. When as shown in FIG. 15, a transverse length of an image surface is assigned X, a longitudinal length of the image surface is assigned Y, an aspect ratio AR is expressed by Equation 2:

$$AR = X/Y \qquad (2)$$

A schematic diagram of an image pickup range of an imaging optical system is shown in FIG. 16, and a schematic diagram of an image pickup range of an image pickup means is shown in FIG. 17. When from FIG. 16, a transverse length of a size of an effective picture of the image pickup range in the image surface of the imaging optical system is assigned X1, a longitudinal length of the size of that effective picture is assigned Y1, and an aspect ratio is assigned AR1, and from FIG. 17, a transverse length of the image pickup range of the image pickup means is assigned X2, a longitudinal length of that image pickup range is assigned Y2, and an aspect ratio is assigned AR2, a ratio of AR1/AR2 is expressed by Equation 3:

$$AR1/AR2 = (X1 \times Y2)/(X2 \times Y1) \qquad (3)$$

In addition, a conceptual diagram of an image pickup

range after the conversion of the aspect ratio made by the anamorphic converter is shown in FIG. 18. In order that the aspect ratio may be suitably converted, it is desirable that a conversion magnifications βx of the anamorphic converter in a transverse direction, and a conversion magnification βy of the anamorphic converter in a longitudinal direction are expressed by Equations 4 and 5, respectively:

$$\beta x = X2/X1 \qquad (4)$$

$$\beta y = Y2/Y1 \qquad (5)$$

From Equations 3 to 5, the condition for ideal aspect ratio conversion is expressed as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1 \qquad (6)$$

Since in actual, an influence of an error of about 10% is visually small, Equation 1 is met to thereby allow the suitable aspect ratio conversion to be realized.

Also, a conceptual diagram of an output image in projecting an image is shown in FIG. 19. It is necessary that in projecting an image, the conversion of the aspect ratio reverse to that in capturing an image is carried out to return the current aspect ratio back to the original aspect ratio. Consequently, a transverse length X4 and a longitudinal length Y4 in FIG. 19 are expressed as follows, respectively:

$$X4 = \beta x' \times X2 \qquad (7)$$

$$Y4 = \beta y' \times Y2 \qquad (8)$$

Here, the conversion magnifications $\beta x'$ and $\beta y'$, when an arbitrary constant is assigned m, are expressed as follows, respectively:

$$\beta x' = m/\beta x \qquad (9)$$

$$\beta y' = m/\beta y \qquad (10)$$

Aspect 2

There is provided an anamorphic converter according to Aspect 1, in which the anamorphic lens is provided within an afocal group.

Aspect 3

There is provided an anamorphic converter according to Aspect 1 or 2, characterized in that both βx and βy are positive values, and the anamorphic converter has positive refracting powers in the cross section X and in the cross section Y.

Aspect 4

There is provided an anamorphic converter according to Aspect 3, further including, from the imaging optical system side in a stated order, a first group of lenses having a negative refracting power, a second group of lenses including at least two or more anamorphic lenses, and a third group of lenses having a positive refracting power.

Aspect 5

There is provided an anamorphic converter according to Aspect 3 or 4, characterized in that the

following relationship is established:

$$1 \leq (AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) < 2.6 \qquad (11)$$

Aspect 4 is concerned with a condition under which the power disposition of the anamorphic converter for carrying out the aspect ratio conversion without the primary image formation by an imaging optical system is suitably prescribed to make the optical performance excellent.

In order that the primary imaging may be prevented from being made, it is necessary that both the focal length conversion magnifications βx and βy are positive values. Moreover, the cross section X and the cross section Y have positive refracting powers, respectively, to thereby reduce the effect of lengthening a focal length. As a result, there is obtained the anamorphic converter of a type having no primary image formation in which for the single imaging optical system, the field angle is prevented from becoming too narrow, and the exit pupil can be held for long.

In Aspect 4, the suitable structure in Aspect 3 is prescribed. In order that the cross section X and the cross section Y may have different conversion magnifications, it is necessary to form an afocal converter (anamorphic converter) having different angular magnifications in the cross section X and the cross section Y by using at least two so-called toric

lenses each having different curvatures in the cross section X and the cross section Y, or at least two cylindrical lenses having a curvature in a certain cross section. In addition, in order that the converter may be disposed on an image side of the imaging optical system, there are required a first group of lenses having a negative refracting power for causing a converged ray from the imaging optical system to diverge, and a group of lenses having a positive refracting power for imaging that ray. Consequently, an optical property of a portion between the first group of lenses having a negative refracting power and the group of lenses having a positive refracting power is made nearly afocal, and a group of lenses including an anamorphic lens is introduced as the second group of lenses, whereby it is possible to attain an anamorphic converter having no primary image formation.

In Aspect 5, there is prescribed a relationship among the focal length conversion magnification βy, and the aspect ratios AR1 and AR2 for preventing the field angle from becoming too narrow while preventing generation of the eclipse in Aspect 3 or Aspect 4.

Equation (11) exhibits a condition under which reduction in the field angle is suppressed while preventing generation of the eclipse following the aspect ratio conversion. When the converter is

disposed on an image side of the imaging optical system, since an image circle is regulated on the basis of the effective diameter on the side of the imaging optical system, the wide angle can not be obtained even if the conversion magnification is made smaller than 1. Consequently, the eclipse is generated in the periphery of the picture.

As shown in FIG. 16, an image circle I1 of the imaging optical system is expressed by Equation 12:

$$I1 = (X1^2 + Y1^2)^{1/2} = Y1 \times (AR1^2 + 1)^{1/2} \quad (12)$$

In addition, as shown in FIG. 17, a width I2 across corners of the image pickup means is expressed by Equation 13:

$$\begin{aligned} I2 &= (X2^2 + Y2^2)^{1/2} \\ &= \beta y \times Y1 \times (AR2^2 + 1)^{1/2} \quad (13) \end{aligned}$$

Here, as shown in FIG. 18, a width I3 across corners of the image which is subjected to the aspect ratio conversion in the anamorphic converter is expressed by Equation 14:

$$\begin{aligned} I3 &= \{(\beta x \times X1)^2 + (\beta y \times Y1)^2\}^{1/2} \\ &= \beta y \times Y1 \times (AR2^2 + 1)^{1/2} \quad (14) \end{aligned}$$

Consequently, in order that the image after the aspect ratio conversion may contain the width across corners of the image pickup means to prevent generation of the eclipse, a relationship of $I3 \geq I2$ must be established. Thus, from Equations 13 and 14, Equations 15 and 11-2 are obtained:

$$I3^2/I2^2 \geq 1 \quad (15)$$

$$\{\beta y^2 \times (AR2^2 + 1)\}/(AR1^2 + 1) \geq 1 \quad (11\text{-}2)$$

As a result, if the lower limit in Equation (11) is exceeded, the eclipse will be generated.

In addition, if the upper limit in Equation 11 is exceeded, then the field angle obtained through the conversion made by the converter becomes narrower than that in the single imaging optical system, so that the image pickup range of the imaging optical system becomes unable to be effectively utilized.

Aspect 6

There is provided an anamorphic converter according to Aspect 1 or 2, in which both βx and βy are negative values, and the anamorphic converter includes at least one negative lens and two or more anamorphic lenses.

Aspect 7

There is provided an anamorphic converter including at least an anamorphic lens disposed on an image side of an imaging optical system, in which when a focal length conversion magnification in an arbitrary cross section X containing an optical axis of the anamorphic converter is assigned βx, and a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, both βx and βy are negative values.

Aspects 6 and 7 are concerned with a condition in which a structure of the anamorphic converter for obtaining the primary image formation through the imaging optical system to convert the aspect ratio is suitably prescribed to make the optical performance excellent.

A conceptual view of the anamorphic converter of a type having primary image formation is shown in FIG. 32. For the optical system for reimaging the primary image of the imaging optical system, it is necessary that both the focal length conversion magnifications βx and βy are negative values. In addition, in order to contain the marginal ray of the imaging optical system, it is necessary that an entrance pupil nearly agrees with the exit pupil of the imaging optical system. Lenses for broadcasting including a lens for a digital cinema become an optical system which has a long exit pupil and hence is nearly telecentric on the image side since they are established on the assumption that the color separation optical system is used. Consequently, an optical system which is at least nearly telecentric on the both sides is required for the converter. As shown in FIG. 32, in case of the anamorphic converter of a type having primary image formation, since an emitted ray from the imaging optical system is made nearly afocal using the positive lens, an increase in

an off-axial chief ray emitted height hb3 from the converter final surface is suppressed to prevent a quantity of marginal light from being reduced. Thus, an off-axial chief ray emitted inclination angle $\alpha b3$ can be made small. As a result, there is an advantage that the exit pupil becomes long, and hence an influence of the color shading due to the color separation optical system is hardly generated. As shown in FIG. 32, from the condition in which the converter is telecentric on the both sides, the anamorphic converter of a type having primary image formation is constituted by at least two groups of positive lenses, and the refracting power of the whole converter takes a minute value in the vicinity of zero.

In addition, since for the primary image obtained through the imaging optical system, the various aberrations such as the chromatic aberration, the antigmatism and the curvature of field are satisfactorily corrected, the chromatic aberration, the antigmatism, the curvature of field and the like of the converter must also be satisfactorily corrected. When a refracting power of an i-th lens of lenses within the converter is assigned Φi, an Abbe's number of the i-th lens of the lenses is assigned νi, and a refracting index of the i-th lens of the lenses is assigned Ni, a chromatic aberration

correction condition is expressed as follows:

$$\Sigma(\Phi i/\nu i) \approx 0 \qquad (16)$$

Also, a Petzval's condition is expressed as follows:

$$\Sigma(\Phi i/Ni) \approx 0 \qquad (17)$$

Here, since in the general optical materials, $\nu i > 0$ and $Ni > 0$ are established, in order to meet Equations (16) and (17), the anamorphic converter having primary image formation must have at least an negative lens in terms of its structure. Moreover, any one of the intervals within the converter is made nearly afocal, and the lens group including the above-mentioned anamorphic lens is introduced, whereby it is possible to attain the anamorphic converter of a primary image formation type.

Aspect 8

There is provided a lens device, including: the anamorphic converter according to any one of Aspects 1 to 7; and the imaging optical system disposed on an object side with respect to the anamorphic converter.

Aspect 9

There is provided an image pickup device, including: the anamorphic converter according to any one of Aspects 1 to 8; an imaging optical system disposed on an object side with respect to the anamorphic converter; and image pickup means disposed on the object side with respect to the anamorphic converter.

The anamorphic lens used in the present invention is used in terms of the concept including a toric lens and a cylindrical lens, and hence means a lens in which a power in the X direction is different from that in the Y direction.

In addition, the anamorphic lens used in the present invention may have a function of a diffraction system.

Moreover, the imaging optical system of the present invention may be a variable power system or a fixed power system (having no variable power).

(First Embodiment)

This embodiment is concerned with an anamorphic converter of a type having no primary image formation.

FIG. 1 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 1 of the present invention.

In addition, a cross sectional view before insertion of the anamorphic converter in Numerical Example 1 is shown in FIG. 20.

FIGS. 21 to 23 show longitudinal aberration views before insertion of the anamorphic converter in Numerical Examples 1, 2, and 3, respectively.

In FIG. 1, reference symbol F designates a group of front focusing lenses having a positive refracting power as a first group. Reference symbol

V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 1. The anamorphic converter AC includes: a first group G1 of lenses

having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the X direction, and has an effect of shortening a focal length in the X direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective area of the image pickup means are as follows:

$$AR1 = 2.35 \qquad (18)$$

$$AR2 = 1.78 \qquad (19)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = 0.947 \qquad (20)$$

$$\beta y = 1.252 \qquad (21)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \qquad (22)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 1.00 \qquad (23)$$

Thus, these values meet the conditions of Equations 1 and 11. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = +32.789 \qquad (24)$$

$$fACy = +69.848 \qquad (25)$$

Thus, both of them have the positive refracting powers and hence meet the condition which is required for the anamorphic converter of the present invention.

A material of the cylindrical lens used in this embodiment is glass. In the following second and third embodiments as well, the same material will be used.

FIGS. 2 to 7 are longitudinal aberration views in the X direction or in the Y direction in Numerical Example 1. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 1, the following values are obtained:

$fx = 9.74$ to 142.93

$fy = 12.88$ to 188.96

$Fx = 1.94$ to 2.19

$Fy = 2.56$ to 2.90

$2\omega = 56.2$ to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-36.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	2.40				
r34=	-7839.440		d34=	1.50	n20=	1.88815	v20=	40.8
r35=	23.812		d35=	11.72				
r36=	-53.891		d36=	1.50	n21=	1.88815	v21=	40.8
r37=	-398.617		d37=	0.20				
r38=	70.482		d38=	6.77	n22=	1.81264	v22=	25.4
r39=	-44.050		d39=	0.31				
r40=	-53.902		d40=	1.50	n23=	1.51825	v23=	64.1
r41=	63.160		d41=	13.52				
r42=	128.438		d42=	4.68	n24=	1.88815	v24=	40.8
r43=	80.144		d43=	0.20				
r44=	42.096		d44=	8.88	n25=	1.48915	v25=	70.2
r45=	-35.579		d45=	1.50	n26=	1.81264	v26=	25.4
r46=	357.584		d46=	0.20				
r47=	199.741		d47=	5.28	n27=	1.48915	v27=	70.2
r48=	46.226		d48=	2.00				
r49=	0.000		d49=	30.00	n28=	1.60718	v28=	38.0
r50=	0.000		d50=	16.20	n29=	1.51825	v29=	64.2
r51=	0.000							

* r40 to r43 indicate the cylindrical lenses. A curvature in the Y direction is zero.

Focal length fx	9.74	37.31	142.93
fy	12.88	49.33	188.96
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

(Second Embodiment)

This embodiment is concerned with an anamorphic converter of a type having no primary image formation.

FIG. 8 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 2 of the present invention. In addition, a cross sectional view before insertion of the anamorphic converter in Numerical Example 2 is shown in FIG. 20.

In FIG. 8, reference symbol F designates a group of front lenses having a positive refracting power as a first group. Reference symbol V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate

for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 2. The anamorphic converter AC includes: a first group G1 of lenses having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the Y direction, and has an effect of lengthening a focal length in the Y direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective

area of the image pickup means are as follows:

$$AR1 = 2.35 \qquad (26)$$

$$AR2 = 1.78 \qquad (27)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = 0.947 \qquad (28)$$

$$\beta y = 1.252 \qquad (29)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \qquad (30)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 1.00 \qquad (31)$$

Thus, these values meet the conditions of Equations 1 and 11. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = +36.688 \qquad (32)$$

$$fACy = +81.334 \qquad (33)$$

Thus, both of them have the positive refracting powers and hence meet the condition which is required for the anamorphic converter of the present invention.

FIGS. 8 to 14 are longitudinal aberration views

in the X direction or in the Y direction in Numerical Example 2. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 2, the following values are obtained:

fx = 9.74 to 142.93

fy = 12.88 to 188.96

Fx = 1.94 to 2.19

Fy = 2.56 to 2.90

2ω = 56.2 to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	-265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-36.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	2.40				
r34=	-406.116		d34=	1.30	n20=	1.88815	v20=	40.8
r35=	27.624		d35=	5.09				
r36=	-34.561		d36=	1.30	n21=	1.88815	v21=	40.8
r37=	376.875		d37=	2.39				
r38=	125.238		d38=	6.87	n22=	1.81264	v22=	25.4
r39=	-35.789		d39=	0.20				
r40=	51.579		d40=	5.00	n23=	1.73234	v23=	54.7
r41=	-179.240		d41=	10.68				
r42=	-89.456		d42=	1.50	n24=	1.83932	v24=	37.2
r43=	57.960		d43=	2.62				
r44=	56.863		d44=	8.20	n25=	1.48915	v25=	70.2
r45=	-31.532		d45=	1.30	n26=	1.81264	v26=	25.4
r46=	-88.322		d46=	0.20				
r47=	41.080		d47=	6.28	n27=	1.48915	v27=	70.2
r48=	-95.210		d48=	2.00				
r49=	0.000		d49=	30.00	n28=	1.60718	v28=	38.0
r50=	0.000		d50=	16.20	n29=	1.51825	v29=	64.2
r51=	0.000							

* r40 to r43 indicate the cylindrical lenses. A curvature in the X direction is zero.

Focal length fx	9.74	37.31	142.93
fy	12.88	49.33	188.96
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

(Third Embodiment)

This embodiment is concerned with an anamorphic converter of a type having primary image formation.

FIG. 24 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 3 of the present invention. In addition, a cross sectional view before insertion of the anamorphic converter in Numerical Example 3 is shown in FIG. 20.

In FIG. 24, reference symbol F designates a group of front lenses having a positive refracting power as a first group. Reference symbol V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate

for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 3. The anamorphic converter AC includes: a first group G1 of lenses having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the Y direction, and has an effect of lengthening a focal length in the Y direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective

area of the image pickup means are as follows:

$$AR1 = 2.35 \qquad (34)$$

$$AR2 = 1.78 \qquad (35)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = -0.947 \qquad (36)$$

$$\beta y = -1.252 \qquad (37)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \qquad (38)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 1.00 \qquad (39)$$

Thus, these values meet the conditions of Equations 1 and 11. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = -684.6 \qquad (40)$$

$$fACy = -1300.2 \qquad (41)$$

Thus, they have large absolute values and small refracting powers, nearly achieving telecentric on the both sides.

FIGS. 25 to 30 are longitudinal aberration

views in the X direction or in the Y direction in Numerical Example 3. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 3, the following values are obtained:

fx = -9.74 to -142.93

fy = -12.88 to -188.96

Fx = -1.94 to -2.19

Fy = -2.56 to -2.90

2ω = 56.2 to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	-265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-36.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	46.70				
r34=	-33.609		d34=	5.65	n20=	1.73234	v20=	54.7
r35=	-11.157		d35=	7.28				
r36=	-7.998		d36=	1.70	n21=	1.67765	v21=	32.1
r37=	58.541		d37=	9.27	n22=	1.62285	v22=	60.3
r38=	-14.431		d38=	20.48				
r39=	-158.737		d39=	0.54	n23=	1.69979	v23=	55.5
r40=	-48.696		d40=	0.15				
r41=	33-722		d41=	3.29	n24=	1.73234	v24=	54.7
r42=	-43.591		d42=	3.69				
r43=	-29.003		d43=	1.58	n25=	1.83932	v25=	37.2
r44=	52.354		d44=	3.63				
r45=	1000.000		d45=	1.70	n26=	1.52033	v26=	58.9
r46=	43.914		d46=	15.60				
r47=	-25.525		d47=	5.25	n27=	1.73234	v27=	54.7
r48=	-23.578		d48=	0.20				
r49=	59.012		d49=	13.97	n28=	1.49845	v28=	83.5
r50=	-22.890		d50=	1.70	n29=	1.83642	v29=	35.0

r51=	-95.543	d51=	0.20				
r52=	31.544	d52=	10.38	n30=	1.62286	v30=	60.3
r53=	-1000.000	d53=	6.55				
r54=	0.000	d54=	33.00	n31=	1.61170	v31=	46.4
r55=	0.000	d55=	13.20	n32=	1.51825	v32=	64.2
r56=	0.000	d56=					

* r41 to r44 indicate the cylindrical lenses. A curvature in the X direction is zero.

Focal length fx	-9.74	-37.31	-142.93
fy	-12.88	-49.33	-188.96
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

As described above, in the anamorphic converter disposed on an image side of the imaging optical system, conversion magnifications of the cross section X and the cross section Y containing an optical axis are regulated and the lens structure is appropriately set, whereby it is possible to attain the anamorphic converter of the rear converter system which is especially most suitable for a converter for the cinema and excellent in optical performance.

(Operation 2)

Aspect 10

An anamorphic converter according to the present invention includes at least an anamorphic lens disposed on an image side of an imaging optical system, and the anamorphic converter is characterized in that when a focal length conversion magnification in an arbitrary cross section X containing an optical

axis of the anamorphic converter is assigned βx, a focal length conversion magnification in a cross section Y containing an optical axis and being perpendicular to the cross section X is assigned βy, an aspect ratio of an image pickup range in an image surface of the imaging optical system is assigned AR1, and an aspect ratio of an effective area of image pickup means is assigned AR2, the following relationships are established:

$$0.9 < (AR1 \times \beta x)/(AR2 \times \beta y) < 1.1 \qquad (1)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) < 1 \qquad (2)$$

Aspect 10 is concerned with a condition under which the conversion magnification of the anamorphic converter is suitably prescribed to thereby carry out the suitable conversion of an aspect ratio without generation of an eclipse.

Equation 1 exhibits with a condition under which the suitable aspect ratio conversion is carried out. When as shown in FIG. 47, a transverse length of an image surface is assigned X, a longitudinal length of the image surface is assigned Y, an aspect ratio AR is expressed by Equation 3:

$$AR = X/Y \qquad (3)$$

A schematic diagram of an image pickup range of an imaging optical system is shown in FIG. 48, and a schematic diagram of an image pickup range of an image pickup means is shown in FIG. 49. When from

FIG. 48, a transverse length of a size of an effective picture of the image pickup range in the image surface of the imaging optical system is assigned X1, a longitudinal length of the size of that effective picture is assigned Y1, and an aspect ratio is assigned AR1, and from FIG. 17, a transverse length of the image pickup range of the image pickup means is assigned X2, a longitudinal length of that image pickup range is assigned Y2, and an aspect ratio is assigned AR2, a ratio of AR1/AR2 is expressed by Equation 4:

$$AR1/AR2 = (X1 \times Y2)/(X2 \times Y1) \qquad (4)$$

In addition, a conceptual diagram of an image pickup range after the conversion of the aspect ratio made by the anamorphic converter is shown in FIG. 50. In order that the aspect ratio may be suitably converted, it is desirable that a conversion magnifications βx of the anamorphic converter in a transverse direction, and a conversion magnification βy of the anamorphic converter in a longitudinal direction are expressed by Equations 5 and 6, respectively:

$$\beta x = X2/X1 \qquad (5)$$

$$\beta y = Y2/Y1 \qquad (6)$$

From Equations 6 to 8, the condition for ideal aspect ratio conversion is expressed as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1 \qquad (7)$$

Since in actual, an influence of an error of about

10% is visually small, Equation 1 is met to thereby allow the suitable aspect ratio conversion to be realized.

Equation 2 exhibits a condition under which an image pickup means having a width across corners smaller than an image size of the main lens is used. In a case where the converter is normally disposed on an image side of the main lens, a transverse aberration of the main lens is magnified at a conversion magnification of the converter. In addition, since the image circle is regulated on the basis of an effective diameter on the main lens side, even if the conversion magnification is made smaller than 1, the promotion of the wide angle can not be realized and hence the eclipse is generated in the periphery of the picture.

As shown in FIG. 48, the image circle I1 of the main lens is expressed by Equation 8:

$$\begin{aligned} I1 &= (X1^2 + Y1^2)^{1/2} \\ &= Y1 \times (AR1^2 + 1)^{1/2} \qquad (8) \end{aligned}$$

In addition, as shown in FIG. 49, the width I2 across corners of the image pickup means is expressed by Equation (9):

$$\begin{aligned} I2 &= (X2^2 + Y2^2)^{1/2} \\ &= Y2 \times (AR2^2 + 1)^{1/2} \qquad (9) \end{aligned}$$

As shown in FIG. 50, the width I3 across corners of the image an aspect ratio of which is converted by

the anamorphic converter is expressed as follows:

$$I3 = \{(\beta x \times X1)^2 + (\beta y \times Y1)^2\}^{1/2}$$
$$= \beta y \times Y1 \times (AR2^2 + 1)^{1/2} \qquad (10)$$

Thus, in order that the width across corners of the image after conversion of the aspect ratio may agree with the image size of the main lens, a relationship of I3 = I1 must be established. Consequently, from Equations 8 and 10, Equations 11 and 11′ are obtained:

$$I3^2/I1^2 = 1 \qquad (11)$$
$$\{\beta y^2 \times (AR2^2 + 1)\}/(AR1^2 + 1) = 1 \qquad (11')$$

Here, when the width I2 across corners of the image pickup means is smaller than the image size I1 of the main lens, even if a left number of Equation 11′ is smaller than 1, no eclipse is generated. Consequently, Equation (2) is met, whereby it is possible to attain the anamorphic converter most suitable for a case where there is used the image pickup means having a width across corners smaller than the image size of the main lens. In addition, since the conversion magnification of the converter can be reduced, the magnification of the aberration of the main lens can be suppressed to make the optical performance excellent. Note that in the present invention, the foregoing is also applied to a case where the use conditions such as zooming, focusing and a stopatic operation are restricted to

substantially magnify the image size of the main lens in using the optical system.

Moreover, a conceptual diagram of an output image in projecting an image is shown in FIG. 51. It is necessary that in projecting an image, the conversion of the aspect ratio reverse to that in capturing an image is carried out to return the current aspect ratio back to the original aspect ratio. Consequently, a transverse length X4 and a longitudinal length Y4 in FIG. 20 are expressed as follows, respectively:

$$X4 = \beta x' \times X2 \qquad (12)$$

$$Y4 = \beta y' \times Y2 \qquad (13)$$

Here, the conversion magnifications $\beta x'$ and $\beta y'$, when an arbitrary constant is assigned m, are expressed as follows, respectively:

$$\beta x' = m/\beta x \qquad (14)$$

$$\beta y' = m/\beta y \qquad (15)$$

Aspect 11

There is provided an anamorphic converter according to Aspect 10, in which the anamorphic lens is provided within an afocal group.

Aspect 12

There is provided an anamorphic converter according to Aspect 10 or 11, characterized in that both βx and βy are positive values, and the anamorphic converter has positive refracting powers

in the cross section X and in the cross section Y.

Aspect 13

There is provided an anamorphic converter according to Aspect 12, characterized in that the anamorphic converter further includes, from the imaging optical system side in a stated order, a first group of lenses having a negative refracting power, a second group of lenses including at least two or more anamorphic lenses, and a third group of lenses having a positive refracting power.

Aspect 12 is concerned with a condition under which the power disposition of the anamorphic converter for carrying out the aspect ratio conversion without the primary image formation by an imaging optical system is suitably prescribed to make the optical performance excellent.

In order that the primary imaging may be prevented from being made, it is necessary that both the focal length conversion magnifications βx and βy are positive values. Moreover, the cross section X and the cross section Y have positive refracting powers, respectively, to thereby reduce the effect of lengthening a focal length. As a result, there is obtained the anamorphic converter of a type having no primary image formation in which for the single imaging optical system, the field angle is prevented from becoming too narrow, and the exit pupil can be

held for long.

In Aspect 13, the suitable structure in Aspect 12 is prescribed. In order that the cross section X and the cross section Y may have different conversion magnifications, it is necessary to form an afocal converter (anamorphic converter) having different angular magnifications in the cross section X and the cross section Y by using at least two so-called toric lenses each having different curvatures in the cross section X and the cross section Y, or at least two cylindrical lenses having a curvature in a certain cross section. In addition, in order that the converter may be disposed on an image side of the imaging optical system, there are required a first group of lenses having a negative refracting power for causing a converged ray from the imaging optical system to diverge, and a group of lenses having a positive refracting power for imaging that ray. Consequently, an optical property of a portion between the first group of lenses having a negative refracting power and the group of lenses having a positive refracting power is made nearly afocal, and a group of lenses including an anamorphic lens is introduced as the second group of lenses, whereby it is possible to attain an anamorphic converter having no primary image formation.

Aspect 14

There is provided an anamorphic converter according to Aspect 10 or 11, in which both βx and βy are negative values, and the anamorphic converter further includes at least one negative lens and two or more anamorphic lenses.

Aspect 14 is concerned with a condition in which a structure of the anamorphic converter for obtaining the primary image formation through the imaging optical system to convert the aspect ratio is suitably prescribed to make the optical performance excellent.

A conceptual view of the anamorphic converter of a type having primary image formation is shown in FIG. 64. For the optical system for reimaging the primary image of the imaging optical system, it is necessary that both the focal length conversion magnifications βx and βy are negative values. In addition, in order to contain the marginal ray of the imaging optical system, it is necessary that an entrance pupil nearly agrees with the exit pupil of the imaging optical system. Lenses for broadcasting including a lens for the digital cinema become an optical system which has a long exit pupil and hence is nearly telecentric on the image side since they are established on the assumption that the color separation optical system is used. Consequently, at least an optical system which is nearly telecentric

on the both sides is required for the converter. As shown in FIG. 64, in case of the anamorphic converter of a type having primary image formation, since an emitted ray from the imaging optical system is made nearly afocal using the positive lens, an increase in an off-axial chief ray emitted height hb3 from the converter final surface is suppressed to prevent a quantity of marginal light from being reduced, and hence an off-axial chief ray emitted inclination angle $\alpha b2$ can be made small. As a result, there is an advantage that the exit pupil becomes long, and hence an influence of the color shading due to the color separation optical system is hardly generated. As shown in FIG. 64, from the condition in which the converter is telecentric on the both sides, the anamorphic converter of a type having primary image formation is constituted by at least two groups of positive lenses, and the refracting power of the whole converter takes a minute value in the vicinity of zero.

In addition, since for the primary image obtained through the imaging optical system, the various aberrations such as the chromatic aberration, the antigmatism and the curvature of field are satisfactorily corrected, the chromatic aberration, the antigmatism, the curvature of field and the like of the converter must also be satisfactorily

corrected. When a refracting power of an i-th lens of lenses within the converter is assigned Φi, an Abbe's number of the i-th lens of the lenses is assigned νi, and a refracting index of the i-th lens of the lenses is assigned Ni, a chromatic aberration correction condition is expressed as follows:

$$\Sigma(\Phi i/\nu i) \approx 0 \qquad (16)$$

Also, a Petzval's condition is expressed as follows:

$$\Sigma(\Phi i/Ni) \approx 0 \qquad (17)$$

Here, since in the general optical materials, $\nu i > 0$ and $Ni > 0$ are established, in order to meet Equations (16) and (17), the anamorphic converter having primary image formation must have at least an negative lens in terms of its structure. Moreover, any one of the intervals within the converter is made nearly afocal, and the lens group including the above-mentioned anamorphic lens is introduced, whereby it is possible to attain the anamorphic converter of a primary image formation type.

Aspect 15

There is provided a lens device, including: the anamorphic converter according to any one of Embodiments 10 to 14; and the imaging optical system disposed on an object side with respect to the anamorphic converter.

Aspect 16

There is provided an image pickup device,

including: the anamorphic converter according to any one of Aspects 10 to 15; an imaging optical system disposed on an object side with respect to the anamorphic converter; and image pickup means disposed on the object side with respect to the anamorphic converter.

The anamorphic lens used in the present invention is used in terms of the concept including a toric lens and a cylindrical lens, and hence means a lens in which a power in the X direction is different from that in the Y direction.

In addition, the anamorphic lens used in the present invention may have a function of a diffraction system.

Moreover, the imaging optical system of the present invention may be a variable power system or a fixed power system (having no variable power).

(Fourth Embodiment)

This embodiment is concerned with an anamorphic converter of a type having no primary image formation.

A specific structure of the anamorphic converter according to the present invention is described next. FIG. 33 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 4 of the present invention. In addition, a cross sectional view before insertion of the anamorphic

converter in Numerical Example 4 is shown in FIG. 52.

FIGS. 53 to 55 show longitudinal aberration views before insertion of the anamorphic converter in Numerical Examples 4, 5, and 6, respectively.

In FIG. 33, reference symbol F designates a group of front lenses having a positive refracting power as a first group. Reference symbol V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 4. The anamorphic converter AC includes: a first group G1 of lenses having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the X direction, and has an effect of shortening a focal length in the X direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective area of the image pickup means are as follows:

$$AR1 = 2.35 \qquad (18)$$

$$AR2 = 1.78 \qquad (19)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = 0.767 \qquad (20)$$

$$\beta y = 1.013 \qquad (21)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \quad (22)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 0.656 \quad (23)$$

Thus, these values meet the conditions of Equations 1 and 2. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = +23.383 \quad (24)$$

$$fACy = +40.894 \quad (25)$$

Thus, both of them have the positive refracting powers and hence meet the condition which is required for the anamorphic converter of the present invention.

A material of the cylindrical lens used in this embodiment is glass. In the following fifth and sixth embodiments as well, the same material will be used.

FIGS. 34 to 39 are longitudinal aberration views in the X direction or in the Y direction in Numerical Example 4. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 4, the following values are obtained:

$fx = 7.90$ to 115.83

$fy = 10.44$ to 153.12

$Fx = 1.57$ to 1.78

$Fy = 2.08$ to 2.35

$2\omega = 56.2$ to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	-265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-36.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	2.40				
r34=	-7839.440		d34=	1.50	n20=	1.88815	v20=	40.8
r35=	23.812		d35=	11.72				
r36=	-53.891		d36=	1.50	n21=	1.88815	v21=	40.8
r37=	-398.617		d37=	0.20				
r38=	70.482		d38=	5.77	n22=	1.81264	v22=	25.4
r39=	-44.050		d39=	0.31				
r40=	-53.902		d40=	1.50	n23=	1.51825	v23=	64.1
r41=	63.160		d41=	13.62				
r42=	128.438		d42=	4.68	n24=	1.88815	v24=	40.8
r43=	-80.144		d43=	0.20				
r44=	29.500		d44=	8.88	n25=	1.48915	v25=	70.2
r45=	-24.900		d45=	1.50	n26=	1.81264	v26=	25.4
r46=	250.300		d46=	0.20				
r47=	139.800		d47=	5.28	n27=	1.48915	v27=	70.2
r48=	-32.300		d48=	2.00				
r49=	0.000		d49=	29.00	n28=	1.60718	v28=	38.0
r50=	0.000		d50=	11.20	n29=	1.51825	v29=	64.2
r51=	0.000							

* r40 to r43 indicate the cylindrical lenses. A curvature in the Y direction is zero.

Focal length fx	7.9	30.24	115.83
fy	10.44	39.98	153.12
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

(Fifth Embodiment)

This embodiment is concerned with an anamorphic converter of a type having no primary image formation.

FIG. 40 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 5 of the present invention. In addition, a cross sectional view before insertion of the anamorphic converter in Numerical Example 5 is shown in FIG. 52.

In FIG. 40, reference symbol F designates a group of front lenses having a positive refracting power as a first group. Reference symbol V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate

for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 5. The anamorphic converter AC includes: a first group G1 of lenses having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the Y direction, and has an effect of lengthening a focal length in the Y direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective

area of the image pickup means are as follows:

$$AR1 = 2.35 \quad (26)$$

$$AR2 = 1.78 \quad (27)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = 0.713 \quad (28)$$

$$\beta y = 0.942 \quad (29)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \quad (30)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 0.567 \quad (31)$$

Thus, these values meet the conditions of Equations 1 and 2. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = +22.999 \quad (32)$$

$$fACy = +38.486 \quad (33)$$

Thus, both of them have the positive refracting powers and hence meet the condition which is required for the anamorphic converter of the present invention.

FIGS. 40 to 46 are longitudinal aberration

views in the X direction or in the Y direction in Numerical Example 5. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 5, the following values are obtained:

fx = 7.34 to 107.72

fy = 9.71 to 142.41

Fx = 1.46 to 1.65

Fy = 1.93 to 2.19

2ω = 56.2 to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	-265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-36.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	2.40				
r34=	-406.116		d34=	1.50	n20=	1.88815	v20=	40.8
r35=	27.624		d35=	5.09				
r36=	-34.561		d36=	1.30	n21=	1.88815	v21=	40.8
r37=	376.875		d37=	2.39				
r38=	125.238		d38=	6.87	n22=	1.81264	v22=	25.4
r39=	-35.789		d39=	0.20				
r40=	51.579		d40=	5.00	n23=	1.73234	v23=	54.7
r41=	-179.240		d41=	10.68				
r42=	-89.456		d42=	1.50	n24=	1.89932	v24=	37.2
r43=	57.960		d43=	2.62				
r44=	42.100		d44=	8.20	n25=	1.48915	v25=	70.2
r45=	-23.300		d45=	1.30	n26=	1.81264	v26=	25.4
r46=	-85.300		d46=	0.20				
r47=	30.400		d47=	6.28	n27=	1.48915	v27=	70.2
r48=	-70.400		d48=	0.50				
r49=	0.000		d49=	29.00	n28=	1.60718	v28=	38.0
r50=	0.000		d50=	11.20	n29=	1.51825	v29=	64.2
r51=	0.000							

* r40 to r43 indicate the cylindrical lenses. A curvature in the X direction is zero.

Focal length fx	7.34	28.12	107.72
fy	9.71	37.18	142.41
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

(Sixth Embodiment)

This embodiment is concerned with an anamorphic converter of a type having no primary image formation.

FIG. 56 is a cross sectional view of lenses in a Y direction and in an X direction when an anamorphic converter is inserted in Numerical Example 6 of the present invention. In addition, a cross sectional view before insertion of the anamorphic converter in Numerical Example 6 is shown in FIG. 52.

In FIG. 56, reference symbol F designates a group of front lenses having a positive refracting power as a first group. Reference symbol V designates a variator for the variable power having a negative refracting power as a second group. The variator V is monotonously moved on an optical axis to an image surface side to thereby carry out the variable power from the wide angle end to the telescopic end. Reference symbol C designates a compensator having a negative refracting power as a third group. The compensator C is nonlinearly moved on the optical axis to an object side while describing a projection locus in order to compensate

for the fluctuation of an image surface following the variable power. The variator V and the compensator C constitute the variable power system.

Reference symbol SP designates a stop, and reference symbol R designates a group of variable power semi-fixed relay lenses having a positive refracting power as a fourth group. Reference symbol P designates a color separation prism, an optical filter or the like which is shown in the form of a glass block in the figure.

The focusing group F, the variator V, the compensator C and the relay group R constitute an imaging optical system.

Next, a description will hereinafter be given with respect to the feature of the anamorphic converter AC in Numerical Example 6. The anamorphic converter AC includes: a first group G1 of lenses having a negative refracting power; a second group G2 of lenses having two cylindrical lenses; and a third group G3 of lenses having an image formation function and a positive refracting power. Each of the cylindrical lenses belonging to the second group G2 has a curvature only in the Y direction, and has an effect of lengthening a focal length in the Y direction. The aspect ratio AR1 of the image pickup range in the image surface of the imaging optical system, and the aspect ratio AR2 of the effective

area of the image pickup means are as follows:

$$AR1 = 2.35 \qquad (34)$$

$$AR2 = 1.78 \qquad (35)$$

Also, the conversion magnification βx in the X direction, and the conversion magnification βy in the Y direction are as follows:

$$\beta x = -0.691 \qquad (36)$$

$$\beta y = -0.913 \qquad (37)$$

Consequently, the values of the conditional equations are obtained as follows:

$$(AR1 \times \beta x)/(AR2 \times \beta y) = 1.00 \qquad (38)$$

$$(AR2^2 + 1) \times \beta y^2/(AR1^2 + 1) = 0.533 \qquad (39)$$

Thus, these values meet the conditions of Equations 1 and 11. Consequently, the anamorphic converter of a built-in converter system is attained which is excellent in the optical performance and free from the eclipse.

In addition, in case of the single anamorphic converter AC, a focal length fACx in the X direction, and a focal length fACy in the Y direction are expressed as follows:

$$fACx = -88.42 \qquad (40)$$

$$fACy = -123.52 \qquad (41)$$

Thus, they have large absolute values and small refracting powers, nearly achieving telecentric on the both sides.

FIGS. 56 to 62 are longitudinal aberration

views in the X direction or in the Y direction in Numerical Example 6. In these figures, fx indicates a focal length in the X direction, fy indicates a focal length in the Y direction, Fx indicates an F number in the X direction, Fy indicates an F number in the Y direction, and 2ω indicates a field angle.

In Numerical Example 6, the following values are obtained:

fx = -7.11 to -104.37

fy = -9.40 to -137.96

Fx = -1.42 to -1.60

Fy = -1.87 to -2.12

2ω = 56.2 to 4.2 degrees

r 1=	1169.481		d 1=	2.40	n 1=	1.81265	v 1=	25.4
r 2=	98.429		d 2=	10.83	n 2=	1.51825	v 2=	64.2
r 3=	-265.170		d 3=	0.20				
r 4=	124.037		d 4=	8.29	n 3=	1.60548	v 3=	60.7
r 5=	-281.395		d 5=	0.20				
r 6=	51.797		d 6=	6.46	n 4=	1.64254	v 4=	60.1
r 7=	97.915		d 7=	Variable				
r 8=	71.045		d 8=	0.90	n 5=	1.82017	v 5=	46.6
r 9=	17.601		d 9=	6.01				
r10=	-21.542		d10=	0.90	n 6=	1.77621	v 6=	49.6
r11=	18.397		d11=	4.63	n 7=	1.85501	v 7=	23.9
r12=	-4295.134		d12=	Variable				
r13=	-27.245		d13=	0.90	n 8=	1.79013	v 8=	44.2
r14=	31.613		d14=	3.84	n 9=	1.85501	v 9=	23.9
r15=	1125.345		d15=	Variable				
r16=	0.000	(Stop)	d16=	1.60				
r17=	10000.000		d17=	4.02	n10=	1.73234	v10=	54.7
r18=	-32.342		d18=	0.20				
r19=	107.938		d19=	3.60	n11=	1.48915	v11=	70.2
r20=	-121.402		d20=	0.20				
r21=	37.891		d21=	7.17	n12=	1.48915	v12=	70.2
r22=	-38.452		d22=	1.20	n13=	1.83932	v13=	37.2
r23=	177.431		d23=	30.00				
r24=	48.564		d24=	4.26	n14=	1.48915	v14=	70.2
r25=	-193.706		d25=	0.20				
r26=	-210.911		d26=	1.20	n15=	1.83932	v15=	37.2
r27=	39.960		d27=	6.49	n16=	1.48915	v16=	70.2
r28=	-33.683		d28=	0.20				
r29=	43.464		d29=	6.21	n17=	1.53430	v17=	48.8
r30=	-30.063		d30=	1.20	n18=	1.80811	v18=	46.6
r31=	113.246		d31=	0.20				
r32=	56.783		d32=	2.98	n19=	1.55098	v19=	45.8
r33=	-10000.000		d33=	46.70				
r34=	-39.609		d34=	5.65	n20=	1.73234	v20=	54.7
r35=	-11.167		d35=	7.28				
r36=	-7.998		d36=	1.70	n21=	1.67765	v21=	32.1
r37=	58.541		d37=	9.27	n22=	1.62286	v22=	60.3
r38=	-14.491		d38=	20.48				
r39=	-150.787		d39=	4.54	n23=	1.69979	v23=	55.5
r40=	-40.896		d40=	0.15				
r41=	36.722		d41=	9.29	n24=	1.73234	v24=	54.7
r42=	-43.594		d42=	3.69				
r43=	-29.003		d43=	1.58	n25=	1.83932	v25=	37.2
r44=	52.354		d44=	3.68				
r45=	800.000		d45=	1.70	n26=	1.52033	v26=	58.9
r46=	40.000		d46=	16.60				
r47=	-21.200		d47=	5.25	n27=	1.73234	v27=	54.7
r48=	-18.900		d48=	0.20				
r49=	47.200		d49=	13.97	n28=	1.49845	v28=	81.5
r50=	-18.300		d50=	1.70	n29=	1.80642	v29=	35.0

r51=	-76.400	d51=	0.20				
r52=	25.200	d52=	10.38	n30=	1.62286	v30=	60.3
r53=	-800.000	d53=	1.00				
r54=	0.000	d54=	29.00	n31=	1.60718	v31=	38.0
r55=	0.000	d55=	11.20	n32=	1.51825	v32=	64.2
r56=	0.000						

* r41 to r44 indicate the cylindrical lenses. A curvature in the X direction is zero.

Focal length fx	-7.11	-27.25	-104.37
fy	-9.4	-36.02	-137.96
Variable spacing			
d7	0.39	33.92	49.55
d12	52.91	14.8	3.78
d15	1.55	6.13	1.53

As described above, in the anamorphic converter disposed on an image side of the imaging optical system, conversion magnifications of the cross section X and the cross section Y containing an optical axis are regulated and the lens structure is appropriately set, whereby it is possible to attain the anamorphic converter of the rear converter system which is especially most suitable for a converter for the cinema and excellent in optical performance for using the image pickup means having a width across corners smaller than an image size of the imaging optical system.